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Research Article

DEMYSTIFYING THE BONDING TO ZIRCONIA: A SYSTEMATIC REVIEW OF THE LITERATURE

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ABSTRACT

Purpose: Adhesion to zirconia is still a challenge.There is no consensus concerning the most effective adhesion protocol for zirconia used in dentistry.This is important particularly for restorations where mechanical retention is deficient. The aim of this systematic review was to analyse the adhesion potential of resin cements to zirconia and to highlight the best surface conditioning method affecting the bond strength results to this substrate.

Materials and Methods: A systematic review of the literature was conducted through the MEDLINE (PubMed) database between 11/01/2011and 11/01/2016.Original scientific papers on the adhesion to zirconia published were included.

The following combination of MeSH terms was used: "dental cements"[Majr] AND "yttria stabilized tetragonal zirconia"[Supplementary Concept]. Two reviewers achieved screening and data abstraction.

Results: The first search provided 69 papers. Then, after selecting only the last 5 years, we obtained 41articles.Titles and abstracts screening yielded 33 articles, out of which 30 were found potentially right to be included (after full text selection).

The most documented surface treatments were:

- Airborne particle abrasion, tribochemical treatment, surface coating, laser treatment, acid treatment and primer treatment, while the cements used belonged mostly to 4 families: MDP, Self-adhesive cements, 4-Meta and Bis-GMA.
- Irrespective of the conditioning method used, the MDP-based cements showed significantly higher bond strength than other types of cements, but this values dropped after artificial aging, which means that the MDP cements still require a previous mechanical treatment to guarantee stability over time.

Conclusion: Within the limitations of our study, it can be concluded that the combination of the tribochemical treatment and the use of MDP based cements is the most effective, durable and safest conditioning method considering the literature included in our work. Further works are still required with more standardisation and focus on the aging factor.

INTRODUCTION

Lately, all-ceramic restorations have been more widely used for their aesthetic result, biocompatibility and good mechanical proprieties. Yttria-stabilized tetragonal zirconia polycrystalline (Y-TZP) ceramics can be indicated as a substitute to conventional metal frameworks. However, the absence of the vitreous phase makes this polycrystalline ceramic unetchable, limiting its adhesive luting potential. Different surface conditioning methods have therefore been suggested to improve the bonding strength of composite cement to zirconia.

Several studies have worked on bond strength to zirconia; different pre-treatment procedures have been tried out, using various laboratory tests, to analyse the bonding effectiveness to zirconia and its durability. But the lack of consensus makes it difficult to obtain the current status of zirconia-bonding technology. Therefore, the purpose of this study was, to evaluate, through a systematic review, the bond strength data of dental cements to zirconia, and (Bömicke, 2016) to identify the optimal surface conditioning method that offers a good bond strength to that substrateand guarantees its stability over time.

MATERIAL AND METHOD

Systematic Search Strategy

Before the beginning of the systematic literature search, the protocol was approved by the authors. An electronic search

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was performed through MEDLINE database (PubMed) (https://www.ncbi.nlm.nih.gov/pubmed). We meant to include articles published in English from "11/01/2011"to "11/01/2016" by using the following combination of MeSH terms:

"Dental cements"[Majr] AND "yttria stabilized tetragonal zirconia"[Supplementary Concept]. Two reviewers achieved screening and data extraction. The literature search was built up in three successive steps as seen in the flow chart below (Figure 1). The first step concerned entering the research equation followed by setting methodological filters. The second step was based ontitle and abstract evaluation. The third one was achieved by reading and screening full-text version of each potentially relevant publication.

Inclusion criteria

Articles were included if all of the following inclusion criteria were existing:

- In vitro studies, randomised trials, systematic reviews and meta-analyses reporting on bonding zirconia to cements not onto dentin or tooth substance.
- Studies that used microtensile, macrotensile, microshear or macroshear presented in MPa.
- In each group in the study, at least the following data were detailed: type of test, mean bond strength.
- The type of cement used and its composition must be reported.
- The factors « aging » and « fatigue simulation » must be described.

Exclusion criteria

Articles were excluded if one of the following exclusion criteria was met:

- Publications that studied the bonding to dentin substrate.
- Studies related to zirconia posts to root dentin and the ones performed with push-out test.
- Articles that reported the bonding of veneering ceramics to zirconia and the phenomena of chipping.
- Studies that focused on bonding glass-infiltrated ceramic or metals or posts or orthodontic brackets made of oxide ceramics.

Two authors extracted the data, and if there was a disagreement, the study was re-evaluated and discussed until consensus was reached.

Air born particle abrasion

Airborne particle abrasion, also called sandblasting, is the most documented technique. It uses in general aluminum oxide particles (Al2O3) but different particle sizes were recommended, and the literature reported various pressures and distances of blasting.

Mean bond strength: Ranged for TBS test between 25,06 and 38 MPa , for the SBS test from 19,1 and 30.5 MPa and µ SBS test 25 and 28,6 MPa which were satisfactory bond strength values.(20 MPa has proven to be clinically sufficient (Papia *et al.* 2014).)

Tribochemical silica sandblasting

When silica-modified alumina particles are used, the procedure is known as tribochemical silica coating, which deposits a silica layer on the zirconia surface to react with a silane that is applied afterward (Sciasci, 2014). The deposition modes are numerous and divided to chair-side methods and laboratory ones.

Mean bond strength: Ranged from 10 to 43 MPa, the values depend on the composition of the primer and/or cement that were used subsequently.

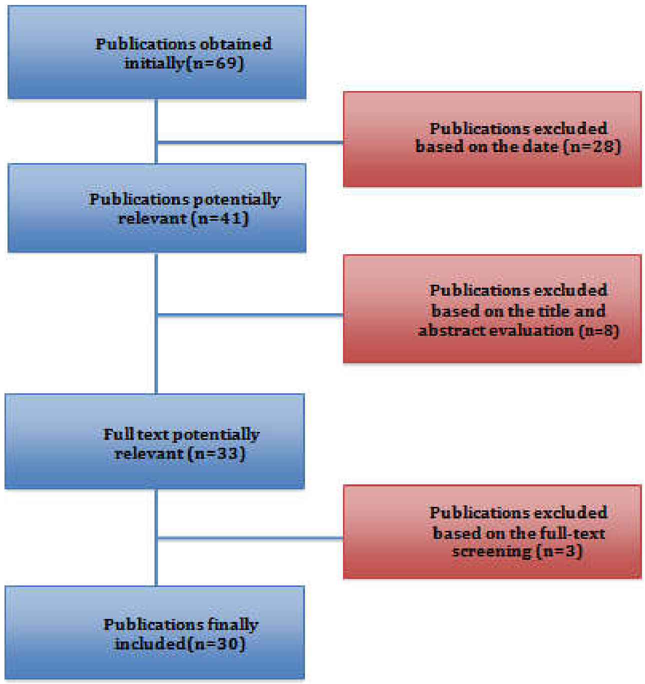

Figure 1. Flow diagram that represent the search strategy and the results of the literature review in each step of the data extraction

Surface coating with a glass or porcelain liner

It is defined as an application of a thin coating of glass liner or porcelain fusion; also known as "the glazing techniques". This layer will be, in general, submitted to an acid attack of HF 10% then followed by an application of silane.

Mean bond strength:SBS test,from 10.73 to 35 MPa,
Tensile test 21.4 ±3.4

The glazing techniques resulted in a significantly enhanced shear bond stress to the resin based cement when compared with the current 'gold standard' tribochemical coating (Everson et al., 2011). This technique is more effective when combined to the Selective infiltration etching technique (SIE) introduced by Aboushelib et al. (2007), which provides an opening of the inter-boundaries spaces by a heat-maturation and thus, inducts a transformation of the dense, non-retentive, low free-energy surface of zirconia to a highly active and retentive surface, enhancing the bond strength up to 32.4 MPa (Samimi, 2015).

- **Laser treatment**

Various laser treatments have been suggested like Nd:YAG, Er,Cr:YSGG, Er:YAG Lasers and used either before or after sintering to reduce the surface damage effects.

Authors	year	Type of study	Surface treatment	Cements and primers	Type of the test	Results
2 Bömicke W & Col.	2016	Randomised trial	-Airborne particle abrasion -Tribochemical pretreatment	Panavia 21 + Clearfil Ceramic Primer Multilink Automix + Monobond Plus BiFix QM + Ceramic bond RelyX Ultimate + Scotchbond Universal	Tensile bond strength	Bond strengths ranged between 4 and 45 MPa (values were lowest in the BiFix QM groups). After long-term aging, the best results were obtained for silica-coated (Rocatec) zirconia samples cemented with Panavia 21/Clearfil Ceramic Primer. This was the only group for which bond strengths were > 10 MPa.
3 Samimi P & col.	2015	In vitro study	Airborne-particle abraded 50-µm Al2O3 (APA); Selective infiltration etching (SIE).	Panavia F2.0, Esthetic Aegis	Microshear bond strength	The highest mean µSBS values were recorded with the MDP-containing resin composite cement (Panavia F2.0) in both SIE (32.4±5.3 MPa) and APA (28.6±8.8 MPa) groups. Water storage significantly reduced the bond strength obtained with the MDP-free cements (Esthetic and Aegis) and in the control group, while the bond strength in SIE and APA groups using the 10- MDP-containing resin composite cement exhibited relatively unchanged values.
4 Pereira LL & Col.	2015	Randomised trial	+/-Al2O3 100 µm	Alloy Primer (AP), Monobond+ (MP), Metal Zirconia Primer (MZP), MZ Primer (MZ), Signum Zirconia Bond (Sg); Singlebond Universal (SbU), Z Prime+ (ZP) + RelyX ARC	Shear bond strength	When universal primers were used alone, SbU presented significantly higher mean SBS (19.5 ± 5.8) that did the other primers (0 to 9.9 ± 6.6) (p = 0.001). When air abraded, the groups AP-A (14.1 ± 6.1), MP-A (15.9 ± 5.4), ZP-A (16.9 ± 7.3), SG-A (19.1 ± 2.1), SbU-A (12 ± 1.5) showed significant differences (p = 0.03). Adhesive performance of all universal primers was enhanced after air abrasion, with the exception of the SbU and MZ primers. After air abrasion, contact angle measurements were lower for the each primer except for MZP.
5 Özcan M, Bernasconi M.	2015	Meta-analysis	169 different surface conditioning methods mainly grouped to physicochemical, physical, chemical	Cements (bis-GMA-, MDP-, and 4-META-based, self-adhesive cements, glass ionomer)	Test methods (Macroshear, Microshear, Macrotensile, Microtensile).	Mean bond strength values ranged between 1.15 (IQR = 3.54) and 8.93 (IQR = 9), and 6.9 (IQR = 0) and 8.73 (IQR = 13.93) MPa for macroshear and macrotensile tests, respectively. After physical conditioning method, MDP monomer based cement presented the highest bond values compared to those of other resin cements using either the macrotensile (no TC: 34.2; IQR = 24.18 MPa, TC: 42.35; IQR = 0 MPa) or microtensile (no TC: 37.2; IQR = 41.5 MPa, TC: 17.1; IQR = 31.15 MPa) test method.
6 Zorzin J	2014	In vitro study	35 µm Al2O3 silanized with ESPE Sil (3M ESPE)	RelyX Unicem Automix 2 G-Cem LinkAce Maxcem Elite (Kerr) self- or dual-curing mode.	Tensile bond strength	Dual curing resulted in significantly (p<0.05) higher tensile bond strengths compared to self-curing, with the exception of RelyX Unicem 2 after thermocycling. Besides, it was concluded that self-adhesive resin cements effectively bond to zirconia without the need for a separate priming procedure, making them an attractive alternative for routine luting of zirconia crowns. However, the resulting bond strength to zirconia varies among the different brands of self-adhesive cements.
7 Sciasci	2015	In vitro study	50 µm Al2O3; 120 µm Al2O3; 30 µm silica-coated Al2O3 (Rocatec Soft) 120 µm Al2O3+ 110 µ silica-coated Al2O3 (Rocatec Plus)	RelyX Luting 2; RelyX ARC; RelyX U100; and Panavia F	Shear Bond strength	For RelyX U100 and Panavia F, any surface treatment usually provides suitable bonding, while for RelyX ARC, silica coating is better indicated. The size of the alumina and silica-coated particles did not influence SBS.
8 Qeblawi DM	2014	In vitro study	50µmAl2O3 30µm silica-modified aluminum oxide particles (Cojet;)+ silane (RelyX ceramic Primer).	SpeedCem[SC] (MDP) (RelyX Unicem Automix [RU]; 3M ESPE) with silica-coating and silanation	Shear bond strength	No significant differences in bond strength to zirconia were observed between a cement with a silane priming step and an methacryloxydecyl dihydrogen phosphate-containing cement without a separate primer. Aging had a significant effect on the shear bond strength of the 2 self-adhesive resin cements to zirconia.

9 Ghasemi A	2014	In vitro study	Er,Cr:YSGG using a power of 2 and 3 W Before and after sintering 50 µm Al2O3;	Panavia F 2.0	Microshear bond strength	Air abrasion is more effective than Er,Cr:YSGG laser irradiation. Although Er,Cr:YSGG laser at only 3 W power after sintering can be regarded as another surface treatment option for roughening the zirconia surface to establish better bond strength with resin cements.
10 Canullo L	2014	In vitro study	110µm Al2O3+ Steam cleaning 110µm Al2O3+ Argon Cleaning 375s 110µm Al2O3+ Argon Cleaning 750s	Z Primer Plus +self adhesive cement (BisCem, Bisco)	Shear bond strength	Plasma of argon appeared to improve bonding between zirconia and resin cement.
11 Maeda	2014	Randomised trial	No Pretreatment	Alloy Primer (AP), Z-Prime Plus (ZP), Signum Zirconia Bond (SZB) + Panavia F, Multilink, seT, and NX3	Shear bond strength	The combination of one resin- based cement containing MDP (Panavia F) and a primer composed of MMA and MDP (signum bond zirconia) improved the bond strength to zirconia based restorations, compared to other combinations of cements and primers.
12 De Souza	2014	Randomised Trial	No pretreatment	Clearfil S3 Bond Plus, Scotchbond U (MDP) +Clearfil SA (MDP) RelyX Ultimate	Microtensile bond strength	The application of an MDP-based adhesive may improve bond strength to zirconia. However, microtensile bond strength results for all groups did not remain stable over 6 months
13 Chen C	2014	Randomised Trial	Tribochemical 110-µm Al2O3	Silane coupling agent Or Z-Prime Plus +Choice (bis-GMA) Or RelyX Unicem (self-adhesive cement)	Shear bond strength	Primers or resin cements containing acidic monomers are able to improve bonding of Y-TZP through simple application procedures.
14 Shin J-y	2014	Randomised Trial	50 µmAl2O3 Tribochimical (CoJet)+silane ESPE1-Sil	Zirconia primer Panavia F2.0 Clearfil SA Luting	Shear bond strength	The airborne abrasion followed by the application of a zirconia primer had the highest shear bond strength (when compared to tribochemical treatment) No difference was shown between the efficacy of Panavia F2.0 resin cement and Clearfil SA Luting.
15 Da Silva	2014	In vitro study	No pretreatment tribochemical silica-coating	ESPE-Sil or Alloy Primer + RelyXArc (conventional) Or RelyX Unicem (self-adhesive)	Microshear bond strength	Irrespective of surface treatments, self-adhesive resin cement was not able to maintain the bond to the Y-TZP ceramic after 6 months of aging in water. Tribochemical silica coating seems to be a more reliable surface treatment for achieving stability in the bond between conventional resin-based cement and yttria-stabilized tetragonal polycrystalline zirconia ceramic.
16 Seabra	2014	In vitro study	50 µmAl2O3	Z-Prime Plus(MDP), All-Bond U (MDP) Scotchbond (MDP) + Composite bis Gma	Shear Bond strength	The new multimode MDP-containing adhesives tested were simple and effective in promoting adhesion between composite resin and zirconia. Z-Prime Plus should be applied in 2 light-polymerized coats to promote multimode adhesives.
17 Erdem	2014	In vitro study	110 µm Al2O3 Tribochemical+Silane Er:YAG laser	Clearfil Esthetic, Panavia F 2.0, Rely X-U100, Super Bond C&B, and Multilink Automix	Shear Bond strength	Regardless of the dual and self-cure resin cement used, laser treatment did not improve resin bond strength but created a smooth surface, with cracks and loss of material MDP–containing adhesive resin cements in combination with air-particle abrasion or tribochemical silane application of ceramic surface produced higher bond strength.
18 Amaral	2014	In vitro study	35 µm Al2O3 Tribochemical (Rocatec or SilJet)+silane Glaze+ etching HF +silane	Z- Prime Plus (ZP), AZ Primer (AZ); Monobond Plus (MP); ScotchBondUniversal (SU); Experimental Adhésive (EA). + Multilink	Tensile strength	Universal adhesives (MP, SU, EA) may be a considerable alternative for bonding to zirconia, but air abrasion is still previously required. Tribochemical treatment followed by silane application also presented high bond strength values.
19 ELsaka	2013	In vitro study	110 µm alumina Methylene chloride H2Cl2 Hot etching solution: methanol+HCl+(FeCl3) 100°C	i CEM Multilink speed	Interfacial fracture test	Adhesion between Y-TZP and self-adhesive resin cements can be improved by the use of H2Cl2 or hot etching surface treatments prior to resin cement application as an alternative technique to airborne-particle abrasion treatment. Improvements in bond strength values were found in the following order: hot solution> H2Cl2 > airborne-particle abrasion > no treatment.

20 Seto	2013	Randomised Trial	50 µmAl2O3	Zirconia primer G-Cem Maxcem Multilink Panavia F RelyX Unicem	Shear Bond strength	Fatigue resistance of two cements (Multilink and Panavia F) was greatly improved by use of a primer and an oxygen-inhibiting gel, as recommended by their respective manufacturers. the application of Oxyguard to Panavia F2.0 produced significantly stronger bonds and a marked improvement in fatigue resistance
21 Baldissara	2013	Randomised Trial	Tribochemical(CoJet Sand) Glaze with feldspathic liner HF for 4 min	ED Primer II +Panavia F RelyX Unicem	Shear Bond Strength	CoJet Sand and liner application effectively improved the SBS between zirconia and luting cements. The best surface treatment × cement combinations were CoJet Sand/RelyX Unicem and Liners/Panavia F. When used on untreated zirconia surfaces, the MDP-containing Panavia F cement showed higher adhesion than self-etching RelyX Unicem.
22 Queirozz	2012	Randomised Trial	silica (Si)-based nano-coating deposited by reactive magnetron sputtering Al2O3	Metal/zirconia primer Multilink, Panavia F, RelyX U100	Shear Bond Strength	the air- abraded group in combination with RelyX U100 resulted in the highest SBS (21.8 ± 6.7 MPa). After aging, the SBS results decreased in the air-abraded groups for all cements (4.54 to 9.44 MPa) and showed no statistical significance compared to the Si-based nanocoated groups (4.24 to 6.44 MPa). Si-based nanocoating on zirconia did not produce a significant difference in terms of bond strength of resin cements compared to air abrasion followed by zirconia primer application.
23 De Sà Barbosa	2012	Randomised Trial	50-µm Al2O3	RelyX Unicem RelyX ARC BisCem G-Cem SeT	Microshear bond strength	There is some evidence suggesting that a better bond to Y-TZP ceramics is obtained using resin cements that contain phosphate ester monomers. Water storage for one year affected the bond strengths of all resin cements tested. Since the bond strength reduction after long-term of water exposure was at least 52%
24 Inokoshi M	2013	Randomised Trial	tribochemical silica sandblasting (CoJet, 3M ESPE)	Clearfil Ceramic Primer Monobond Plus + Clearfil Esthetic Cement (BisGma) Panavia F2.0 (MDP)	Micro-tensile bond strength	Sandblasting appeared indispensable for the MDP-based and more hydrophilic composite cement Panavia F2.0 (Kuraray). As a standard procedure to durable bond zirconia to tooth tissue, both mechanical (tribochemical silica coating) and chemical (silane/MDP-combined ceramic primers) is clinically highly recommended.
25 Usumez A	2012	In vitro study	110 µm Al2O3 (Nd:YAG) laser Feldspathic Glaze+HF 9.5 %	Clearfil Esthetic Cement	Shear Bond Strength	The Nd:YAG laser-irradiated specimens resulted in both increased surface roughness and bond strength of the resin cement. The highest surface roughness and bond strength values were achieved with short pulse duration
26 LH silva	2012	Randomised Trial	Primer Heat- Treatment (20°C, 45°C, 79°C, 100°C).	Metal/zirconia primer +Panavia F	Shear bond strength	Even if heat treatment of the metal/zirconia primer improves early bond strength, it is not effective for bond improvement under aging and therefore should not be recommended.
27 Lorenzoni FC	2012	Randomised Trial	Alkaline Solution NaOH	Alloy Primer Z-Primer Plus Rely X U100	Shear bond strength	The use of a NaOH solution may have modified the reactivity of the Y-TZP surface, whereas the employment of an MDP/VBATDT–based primer enhanced the Y- TZP bond strength.
28 Lung	2012	In vitro study	Tribochemical Espe-Sil Silane 3-acryloxypropyl trimethoxysilane bis-1,2triethoxysilylethane bis[3trimethoxysilylpropyl]amine	RelyX Unicem	Shear bond strength	The results suggest that the combination of functional (3-acryloxypropyl)trimethoxysilane with cross-linking bis [3-(trimethoxysilyl)propyl]amine showed superior hydrolytic stability than with bis-1,2-(triethoxysilyl)
29 Everson P	2011	Randomised Trial	Al2O3 25 µm Tribochemical (Cojet) Glaze+10% HF acid +silane	Rely-X Ceramic Primer +RelyX Unicem	Shear bond strength	The glazing techniques used in the current investigation resulted in a significantly enhanced shear bond stress to the resin based cement when compared with the current 'gold standard' tribochemical coating.
30 Valentino TA	2012	Randomised Trial	Al2O3 50µm Al2O3 110µm Glaze+10% HF acid +silane	Scotchbond Ceramic Primer +Enforce resin cement	Microshear bond strength	Treatment of zirconia ceramic surfaces with a glaze of low-fusing porcelain significantly increased significantly the bond strength of a dual-cure resin luting agent to the ceramic surface

Mean bond strength: µSBS test for Er, Cr: YSGG from 29.51 to 34.92 MPa (Ghasemi and al)

SBS test for Nd: YAG from 6.99 to 8, 17 MPa (Usumez and al.)

- **Primer treatment**

The use of primers is widely described. There are a large variety of adhesive systems used, and the most documented are those that contain functional monomers. The presence of acidic monomers in primers, such as MDP, allows the formation of covalent bonding to the zirconia surface and the copolymerization to methacrylate groups in resin cements. Some studies tested experimental primers while some others studied the heat effect on the bond strength. Bondstrength: for the Tensile test: from 9.3 (±3.5) to 25.8 (±5.5) MPa without alumina sandblasting and from 25.1 (±3.7) to 33.8 (±4.3) MPa after alumina abrasion (Amaral, 2014).

- **Acidic or alkaline treatment**

One study investigated the use of two acidic solutions: Methylene chloride H2Cl2 and a hot etching solution: methanol+HCl+(FeCl3) at 100°C. It has concluded that the adhesion between Y-TZP and self-adhesive resin cements can be improved by the use of H2Cl2 or hot etching surface treatments prior to resin cement application as an alternative technique to airborne-particle abrasion treatment. Improvements in bond strength values were found in the following order: hot solution> H2Cl2 > airborne-particle abrasion > no treatment (El saka 2013). Another study assessed the use of an alkaline solution made of NaOH combined with a zirconia primer and showed that the use of the NaOH solution may have modified the reactivity of the Y-TZP surface, and so improved the wettability whereas the employment of an MDP/VBATDT–based primer enhanced the Y- TZP bond strength (Lorenzoni, 2012).

DISCUSSION

The results of our review revealed that there are large variety of surface treatments, different testing methods, and heterogeneity of protocols, which makethe comparison of the studies difficult. In our review, we focused on the interface between the zirconia and the resin cement not the one to dentin, to be more precise because it's the weakest interface. The preliminary condition for an effective bonding onto any material is to guarantee a clean surface free of contaminants (Ozcan and al). Different methods were proposed, ranging from grinding zirconia specimen with silicone carbide abrasive papers to cleaning with Plasma of Argon, which improves also the wettability of the zirconia and thus it enhances the bond strength. Additionally, several conditioning methods have been encountered but they mainly belong to three groups: physical (airborne particle abrasion, laser), chemical (acid etchant, functional monomers…), and physico-chemical pretreatment (tribochemical, or laser followed by primer, selective infiltration etching technique…). It is problematic to make any statements based on the results shown by each study. This is partly because different brand names of zirconia are tested and they are tested in different modes.The results are consequently dispersed. The most frequently documented method was the air born particle abrasion (APA) with alumina (Al2O3) but again; there was no standardization of the size of particles used (ranged from 30µm to 110µm). Some authors stated that large grains of Al2O3 or powerful pressure might cause tetragonal to monoclinic phase transformation, which may be detrimental for the durability of this ceramic (Pereira and al). It was also specified that greater pressure produced a rougher surface but this might be outweighed by a greater number of voids at the bonding interface, caused by trapped air or insufficient wetting during cementation (Bomicke and al). The air abrasion before sintering was also reported to be effective and producing less phase transformation. According to the systematic review achieved by Papia and al. 2013; smaller particles with a decreased blasting pressure could minimize the surface defects but, by contrast, it may not be sufficient to create micromechanical retention and may only polish the cementation surface. It has been also noticed that the blasting is better realised in 45 degrees instead of 90 degrees, since this has been shown to result in asignificantly better roughness and thus a higher bond strength (Bomicke and al.). In opposition, a new nano-technology was developed by Aboushelib et al. named "the selective infiltration etching (SIE) technique'' that transforms the dense, non-retentive, low free-energy surface of zirconia to a highly active and retentive surface. Some studies have suggested that the SIE technique can establish a strong, stable, and durable bond to zirconia substrates (3). A recent Meta-analysis (Ozcan et al 2015) searched for the highest bond values of adhesion to zirconia, and reported that physical (subtractive) surface conditioning in addition to an MDP-monomer based cement exhibited the best bond strength results (ranging from 17.1 to 42.35 MPa, depending on the aging and testing method); this is considered the recommended bonding method. Another recently developed method of increasing the surface roughness utilizes lasers, which have the advantage of the chair-side execution. Laser devices such as Er: YAG, CO2, and Nd: YAG have been employed by many researchers to establish the surface roughness and irregularity. Er, Cr: YSGG is another effective laser system that has been studied on other substrates. However, the literature contains only limited data regarding this laser system in surface treatment of Y-TZP. Some authors, concluded that Er: YAG laser treatment did not improve resin bond strength but created a smooth surface, with cracks and loss of material while others suggest the use of short pulse duration of laser to diminish the occurrence of the crack-effect.

Besides, the most commonly used and documented test in the literature was the Macro-Shear bond strength test, for its simplicity.However this one was widely criticized (2,3,5) because of its dissimilar stress distribution along the interface, and because it's less discriminative than the other types of tests included in our review.Conversely, Tensile testing is more discriminating but requires an appropriate alignment of the test specimens to warranty centric loading, leading to uniform force distribution along the bonding interface (2,6). Moreover, this test is heavy, technique sensitive, and demands careful handling of fragile specimens. (3, 12) Finally, not all the studies retrieved employed the artificial aging test, or used it but in different ways. Some authors suggested the thermocycling test for simulating the fatigue, however the number of cycles and the temperature used varied. Whileothers used the water storage but the time of storage and the area in contact with water differed widely, which makes this parameter un-interpretable.

Conclusion

Within the limitations of our study, it can be concluded that the combination of the tribochemical treatment and the use of MDP based cements is the most effective, durable and safest conditioning method considering the literature included in our work. Further works are still required with more standardisation and focus on the Aging factor.

The authors declared no conflicts of interest related to this work

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